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International application number: PCT/AU05/000112

International filing date: 31 January 2005 (31.01.2005)

Document type: Certified copy of priority document

Document details: Country/Office: AU
Number: 2004900407
Filing date: 30 January 2004 (30.01.2004)

Date of receipt at the International Bureau: 15 February 2005 (15.02.2005)

Remark: Priority document submitted or transmitted to the International Bureau in compliance with Rule 17.1(a) or (b)

World Intellectual Property Organization (WIPO) - Geneva, Switzerland
Organisation Mondiale de la Propriété Intellectuelle (OMPI) - Genève, Suisse

PCT/AU2005/000112

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I, JANENE PEISKER, TEAM LEADER EXAMINATION SUPPORT AND SALES hereby certify that annexed is a true copy of the Provisional specification in connection with Application No. 2004900407 for a patent by TECHNOLOGICAL RESOURCES PTY LTD as filed on 30 January 2004.

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Ninth day of February 2005

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APPLICANT: TECHNOLOGICAL RESOURCES PTY. LIMITED

AUSTRALIA

PATENTS ACT 1990

PROVISIONAL SPECIFICATION

FOR THE INVENTION ENTITLED:

"RECYCLE OF STEELMAKING SLAG TO A DIRECT SMELTING PROCESS"

The invention is described in the following statement:-

Field of the Invention

The present invention relates to a direct smelting process and an apparatus for producing molten ferrous metal, typically iron and/or ferrous metal alloys.

The present invention further relates to an integrated steelmaking process and apparatus including a steelmaking process and a direct smelting process.

Background of the Invention

During traditional iron and steelmaking processes, fluxes such as burnt lime, limestone, dolomite and/or silica are added to produce slag. Both ironmaking slag and steelmaking slag are considered to be waste products of their respective processes.

Steelmaking slag typically contains iron units in the form of FeO, as well as 25 to 35% CaO, typically as lime. When the steelmaking slag is disposed of in accordance with prior art practice, the iron and lime units are lost.

Significant economic and environmental benefits would be gained if it were possible to recover or reuse iron and lime units from steelmaking slag.

Recycling of steelmaking slag to prior art ironmaking vessels such as traditional blast furnaces in order to recover or reuse the iron and lime units is not considered to be a viable option. One reason for this is that phosphorus in feed materials that are supplied to typical blast furnaces tends to partition to the molten iron produced in the furnace. When this molten iron is subsequently supplied to a steelmaking vessel, the phosphorus partitions into the steelmaking slag in order to produce steel of required chemistry. Thus, recycling steelmaking slag to a typical blast furnace is not practical and would simply result in an increasing phosphorus load in down stream steelmaking

vessels. This is undesirable.

Whilst blast furnaces are the traditional option for producing iron from iron ore, various direct smelting processes have been proposed with a view to avoiding disadvantages of blast furnaces, such as the need for sintering and cokemaking operations. The term "direct smelting" is used to refer to smelt reduction processes that directly supply metalliferous feed material to a molten bath. Such direct smelting processes include, by way of example, the Romelt, DIOS (Direct Iron Ore Smelting), and HIsmelt processes.

The Romelt process operates at ambient pressure using a molten metal and slag bath with ore fines and non-coking coal dropped in from above. Oxygen and an air/oxygen mixture are injected at each of two elevations through side tuyeres to stir the melt and post-combust bath gas.

The DIOS process is another molten metal and slag bath-based process and operates under pressure (1 to 2 bar g) and uses top-feed of coal and ore. Unlike Romelt, it uses a top lance for oxygen injection and has a fluidised bed system for iron ore pre-reduction. In the smelter, most of the reduction occurs in a foamy slag layer. There are significant temperature and FeOx gradients within the reactor (higher temperatures and higher FeOx levels at the top of the slag layer).

The HIsmelt process developed by the applicant is another molten metal and slag bath-based process and differs from 'deep slag' smelters such as DIOS and Romelt in that the solids fed to the vessel are injected significantly deeper into the melt. This leads to stronger mixing in the vessel, with hardly any temperature gradients in the liquid. The HIsmelt process is described, by way of example, in International applications PCT/AU96/00197 (WO 96/31627) and PCT/AU01/00222 (WO 01/64960) in the name of the applicant

and the disclosure in these International applications is incorporated herein by reference.

It has previously been reported that the HIsmelt process is able to process iron ores such as high phosphorus Brockman ores and produce a pig iron with less than 0.05% phosphorus for downstream steelmaking. In contrast to the traditional blast furnace, the HIsmelt process has a more oxidising slag which results in extremely effective partitioning of phosphorus to the slag. During pilot plant testing it was reported by the applicant that 90 to 95% of the phosphorus fed to the HIsmelt pilot plant vessel reported to the slag. The DIOS and Romelt processes are also believed to preferentially partition phosphorus to slag.

Summary of the Invention

The present invention is based on the realisation that the ability of the HIsmelt process to efficiently partition phosphorus to the slag makes it possible to use steelmaking slag as a flux in a direct smelting vessel for the production of iron without adversely affecting the quality of the iron produced within the vessel. In particular, it is possible to recover the iron and reuse the lime units in the steelmaking slag without adversely affecting the quality of the iron produced by the vessel.

The present invention is based on the further realisation that steelmaking slag can be recycled to any direct smelting process provided that the direct smelting process is conducted under conditions whereby phosphorus partitions preferentially to the slag rather than the hot metal and should thus not be limited to the use of only the HIsmelt process.

It has further been realised that the lime units present in the steelmaking slag may be utilised to reduce the consumption of fresh lime as the flux for the ironmaking

process.

According to the present invention there is provided a direct smelting process for producing ferrous metal in a vessel containing a molten bath of metal and slag, the process comprising the steps of:

(a) supplying a ferrous feed material, a solid carbonaceous material, and a slag-forming flux into the bath, with the flux comprising at least a portion of steelmaking slag;

(b) injecting an oxygen-containing gas into the vessel; and

(c) controlling conditions within the vessel to smelt the ferrous feed material to ferrous metal in the bath and to substantially partition phosphorus to the slag.

In many situations it may be impractical to rely solely on the use of steelmaking slag as the flux due to the steelmaking slag typically comprising only 25 to 35 wt% CaO and the other constituents of the slag not being suitable as ironmaking flux. Thus, for a known addition of lime, three times the tonnage of steelmaking slag would be required. In these situations it is appropriate to add one or more additional slag forming agents.

Preferably, the flux further comprises one or more than one additional slag forming agent in addition to the steelmaking slag.

Preferably, the additional slag forming agent comprises calcium oxide. More preferably, the calcium oxide is in the form of lime, burnt lime, dolomite or combinations thereof.

Preferably, step (c) comprises controlling conditions within the vessel to partition phosphorus to the slag by maintaining the slag in an oxidising condition whereby the partition ratio of phosphorus in the metal to phosphorus in the slag is

at least 1:5, and preferably 1:10. Preferably it is in the range of 1:10 - 1:30.

Preferably, the slag temperature is in the range of 1350 - 1450°C and the amount of FeO in the slag is at least 3%.

The ratio of the one or more than one additional slag forming agent to the steelmaking slag will be a function of a plurality of factors including, but not limited to, the size of the metallurgical vessel, the operating temperature, the rates of feeding the ferrous feed material, solid carbonaceous material, and flux to the vessel, the rate of removal of the slag, and the slag inventory in the vessel.

Preferably, the amount of steelmaking slag is at least 50% of the total amount of the slag forming flux.

Preferably, step (a) comprises injecting the ferrous feed material and the solid carbonaceous material into the vessel.

The steelmaking slag added in step (a) may be sourced from any steelmaking facility using any known steelmaking process including but not limited to any of the BOF processes and/or electric arc furnaces (EAF). In either case, preferably the steelmaking slag is cooled in accordance with known techniques so as to be in the form of pellets, granules or powder.

It is preferred that the steelmaking slag be generated within an integrated steelmaking facility including at least one direct smelting vessel and one steelmaking vessel at a single site.

The integrated facility may further be provided with at least one other ironmaking vessel such as a traditional blast furnace. In this scenario, hot metal from one or both of the direct smelting vessel and the ironmaking vessel is fed to the steelmaking vessel. The steelmaking vessel is operated

in accordance with known prior art steelmaking practice to produce ferrous metal alloys (typically steel) and steelmaking slag. In the integrated steelmaking facility the steelmaking slag is recycled as part of the flux to the direct smelting vessel.

According to the present invention, there is also provided an integrated steelmaking process comprising the steps of:

(a) producing steel and steelmaking slag in a steelmaking vessel;

(b) producing a molten ferrous metal from a ferrous feed material in a direct smelting process in a direct smelting vessel containing a molten bath of metal and slag;

(c) adding a portion of the steelmaking slag as a slag-forming flux to the direct smelting vessel; and,

(d) controlling the direct smelting process to smelt the ferrous feed material and substantially partition phosphorus to the slag.

Preferably, the direct smelting process is the HIsmelt process.

Preferably, the flux further comprises one or more than one additional slag forming agent in addition to the steelmaking slag.

Preferably, the additional slag forming agent comprises calcium oxide. More preferably, the calcium oxide is in the form of lime, burnt lime, dolomite or combinations thereof.

Preferably, the integrated steelmaking process further comprises the step of feeding the molten ferrous metal produced in step (b) to the steelmaking vessel of step (a).

Preferably, the integrated steelmaking process comprises cooling the steelmaking slag prior to adding at least a portion of the steelmaking slag as the flux to the direct smelting vessel.

More preferably, the integrated steelmaking process comprises cooling the slag and then subjecting the cooled steelmaking slag to magnetic separation to recover ferrous metal alloys carried over in the slag.

Preferably, the integrated steelmaking process further comprises reducing the size of the cooled steelmaking slag prior to adding the steelmaking slag as the flux to the direct smelting vessel. The preferred size range is 0 to 6mm size range.

Preferably, the steelmaking slag comprises at least 50% or more % by weight of the total weight of flux added to the direct smelting process.

Preferably, the integrated steelmaking process comprises reheating the cooled steelmaking slag prior to adding the steelmaking slag as a flux. Preferably, the steelmaking slag is blended with the ferrous feed material and the combined materials are heated to between 400 - 900°C.

According to the present invention, there is also provided a smelting apparatus for producing metal from a ferrous material by a direct smelting process, the apparatus comprising:

(a) a smelting vessel for containing a bath of molten metal and slag, the vessel comprising at least one lance for injecting an oxygen-containing gas into the vessel, at least one solids feed means for supplying solid feed materials into the molten bath , the solid feed materials comprising ferrous material, a carbonaceous material, and flux comprising at least in part steelmaking slag, and a means for tapping molten metal and slag from the vessel; and,

(b) a means for processing steelmaking slag as a feed material to the direct smelting vessel.

Preferably, the means further includes a means for preheating the steelmaking slag and ferrous material. Any suitable means for preheating may be used including but not limited to a shaft furnace or a fluidised bed.

Preferably, the flux further comprises one or more than one additional slag forming agent in addition to the steelmaking slag, such as CaO, and the means for processing steelmaking slag further comprises a means for controlling the ratio of steelmaking slag to additional slag forming agent in the flux.

Preferably, the solids feed means includes a hot solids feed material injection system for the preheated steelmaking slag.

According to the present invention, there is also provided an integrated steelmaking plant that comprises the above-described smelting apparatus for producing metal from a ferrous material by a direct smelting process and a steelmaking apparatus for producing steel and steelmaking slag.

Preferably, the means for processing steelmaking slag includes a means for cooling steelmaking slag from the steelmaking apparatus and size reduction of the cooled slag.

Brief Description of the Drawings

The preferred embodiments of the present invention are now described, by way of example only, with reference to the accompanying drawings, of which:

Figure 1 illustrates schematically a first embodiment of a process flowsheet;

Figure 2 illustrates schematically a second embodiment of a process flowsheet; and,

Figure 3 illustrates schematically a third embodiment

of a process flowsheet.

Detailed Description of the Preferred Embodiments of the Invention

With reference to Figure 1, there is provided an ironmaking unit including a preheater, typically a shaft furnace or a fluidised bed, and a direct smelting vessel that is suitable particularly for operation by the HIsmelt process as described in International patent application PCT/AU96/00197, the contents of which are incorporated herein by reference.

In use, steelmaking slag obtained from any external source is screened to 0 to 6mm size and is fed to the preheater. Iron ore fines are also fed to the preheater.

The steelmaking slag and the iron ore are heated to a temperature in the range of 400 - 900°C and are blended together or fed separately to the direct smelting vessel. The direct smelting vessel includes injection lances (not shown) capable of receiving hot solids from the preheater and injecting the hot ore fines and hot steelmaking slag at a temperature of the order of 350 - 850°C into the vessel.

The direct smelting vessel is fed with a carbonaceous material, typically coal and additional slag-forming fluxes, typically lime.

The HIsmelt process also operates with air or oxygen-enriched air and therefore generates substantial volumes of offgas which may be used for preheating the materials fed to the direct smelting vessel.

The ironmaking unit is further provided with a means for controlling the ratio of lime to steelmaking slag fed to the direct smelting vessel such that the steelmaking slag is at least 50% of the overall flux addition.

The process conditions within the direct smelting vessel are controlled such that the phosphorus in any of the solid materials fed to the vessel partitions preferentially to the slag. In the case of the HIsmelt process, this is achieved by ensuring that the FeO in slag is in the range 4 - 6% and the temperature is in the range of 1400 - 1450°C. Under these process conditions, the partition ratio of phosphorus in the slag to phosphorus in metal is in the range of 5:1 to 20:1.

The hot metal produced in the direct smelting vessel is sufficiently low in phosphorus (less than 0.05%) to be readily used as a feed material to a downstream steelmaking facility (not shown) which may be located on the same or at another site.

With reference to Figure 2, there is provided an integrated steelmaking plant comprising one or more than one BOF and a direct smelting unit for producing hot metal as a feed to the one or more than one BOF. The steelmaking slag from the BOF is recycled to form one component of the slag-forming flux to the direct smelting unit. The direct smelting unit is operated in the manner described above with reference to Figure 1.

The one or more than one BOF is typically also charged with scrap metal prior to the addition of the ladles of hot metal from the direct smelting unit. Typically, the scrap is charged first before the hot metal to avoid splashing. After the scrap is charged, the hot metal is charged into the BOF. Based on the chemistry of the charge and the temperature and the specific alloy being produced in the steelmaking process, the amounts of flux and oxygen added to the BOF are calculated. As for ironmaking, the typical flux added includes CaO (from burnt lime) and MgO (from dolomitic lime).

When the oxygen blow is finished, the steelmaking slag is allowed to float to the top of the bath of the molten steel. The steel is tapped from the BOF followed by tapping of the steelmaking slag.

The steelmaking slag is typically tapped into slag pots (not shown) and either quenched or allowed to cool. The cooled slag is fed to a means for processing the steelmaking slag, which may include size reduction apparatus such as crushers and screens and/or magnetic separators for recovering carried over steel. The cooled and screened steelmaking slag is then fed to a preheater as described above with reference to Figure 1.

In the arrangement of Figure 3, in use, the steelmaking furnace is charged with hot metal from a direct smelting vessel as described above with reference to Figure 2 as well as hot metal from a traditional blast furnace. The steelmaking slag generated from the steelmaking furnace is recycled to the direct smelting furnace in the manner described above with reference to Figure 2. As the traditional blast furnace is not able to tolerate high phosphorus feeds, the steelmaking slag is not recycled as a flux to the blast furnace. The typical partition ratio of phosphorus in the slag to phosphorus in the metal for a blast furnace is 0.1 compared with 10 to 20 for the HIsmelt process.

The present invention has a number of advantages over the prior art, including:

(a) reducing the amount of waste steelmaking slag required to be disposed of from a steelmaking facility;

(b) recovering lime units and iron units in the steelmaking slag; and,

(c) reducing the quantity of fresh lime required to be fed to an ironmaking process when using recycled steelmaking slag.

Many modifications may be made to the embodiments of the present invention described above without departing from the spirit and scope of the invention.

For example, whilst the embodiments of the present invention have been described in the context of the use of the HIsmelt process, it is understood that the present invention is applicable to any ironmaking process whereby the phosphorus fed to the ironmaking process reports preferentially to the ironmaking slag. Such other ironmaking processes include by way of example the Romelt and DIOS processes.

In addition, whilst the embodiments of the present invention include preheaters, the present invention extends to arrangements that do not include preheaters.

Dated this 30th day of January 2004

AUSTRALIAN ENGINEERING CORPORATION PTY LTD

By Its Patent Attorneys
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Fellows Institute of Patent and Trade Mark Attorneys of Australia

Figure 1

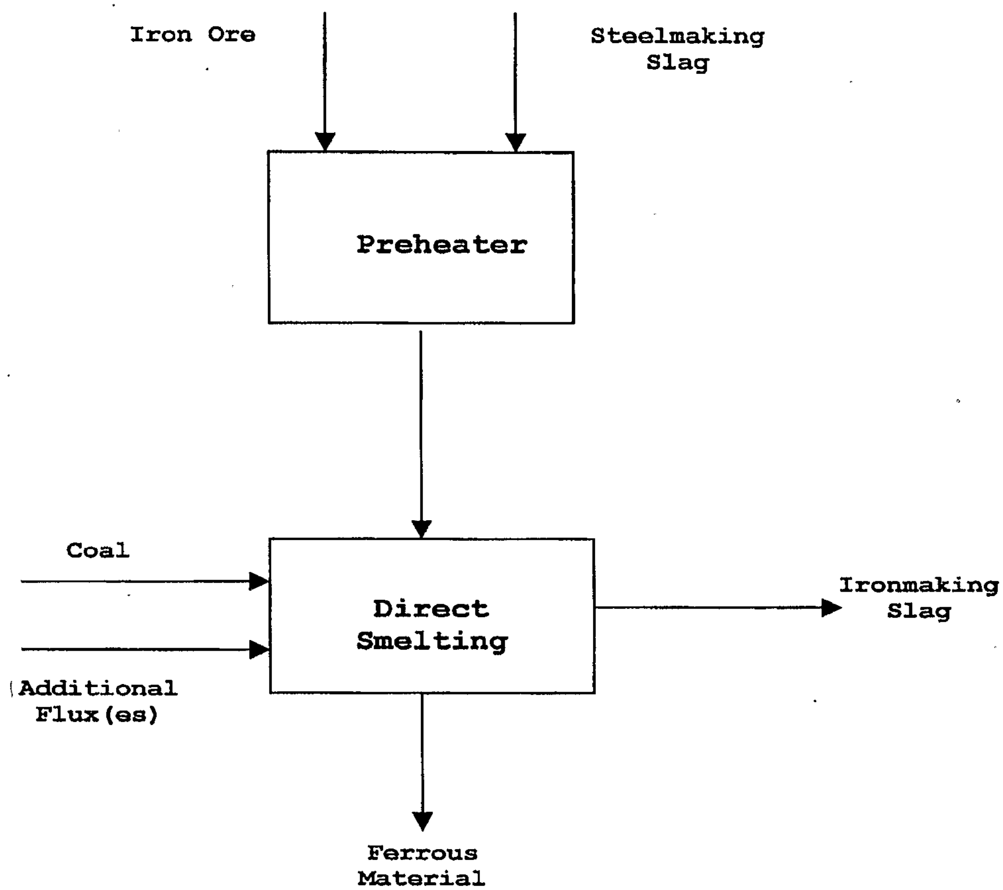

Iron Ore
Steelmaking Slag
Preheater
Coal
Direct Smelting
Ironmaking Slag
Additional Flux(es)
Ferrous Material

Figure 2

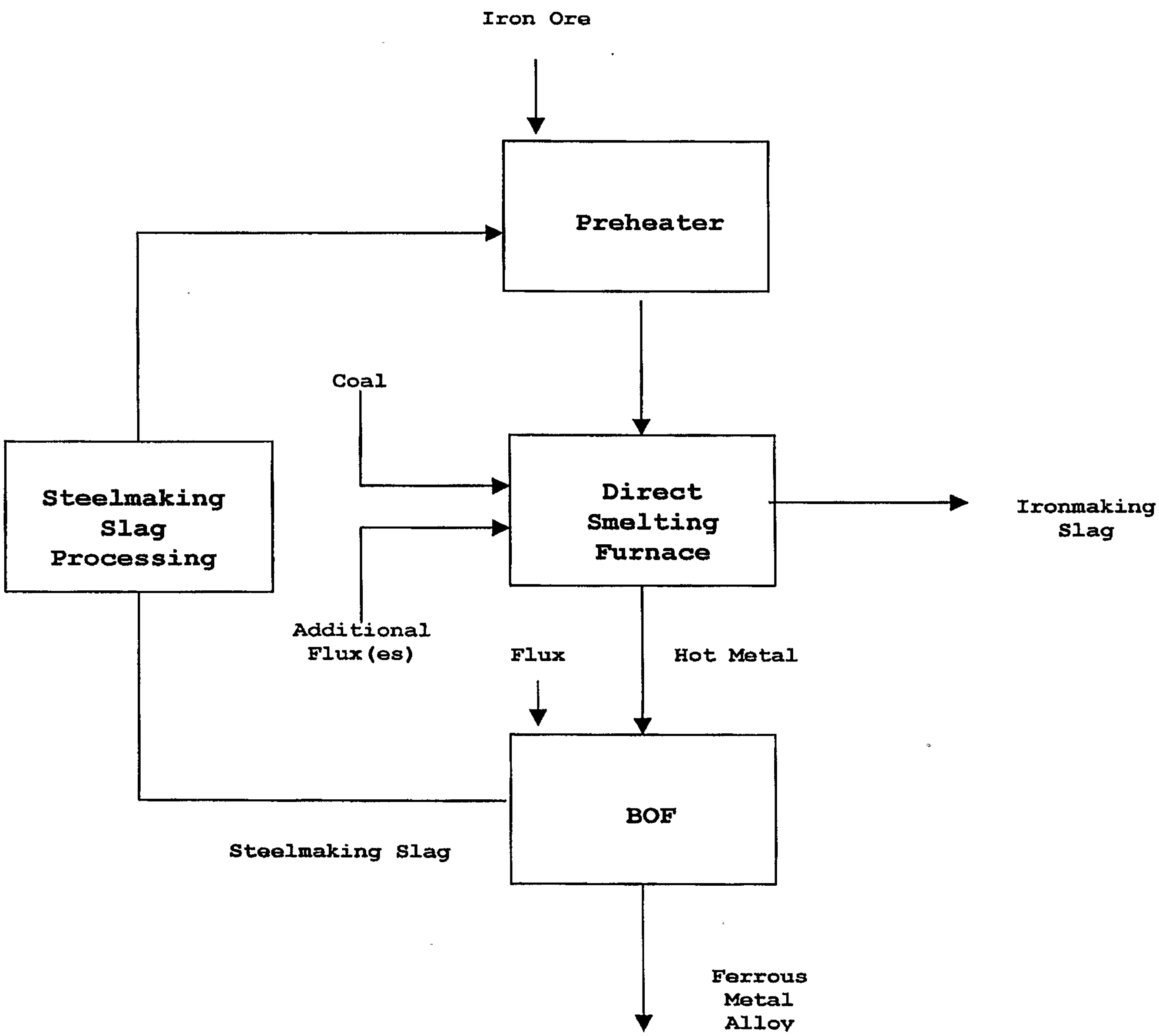
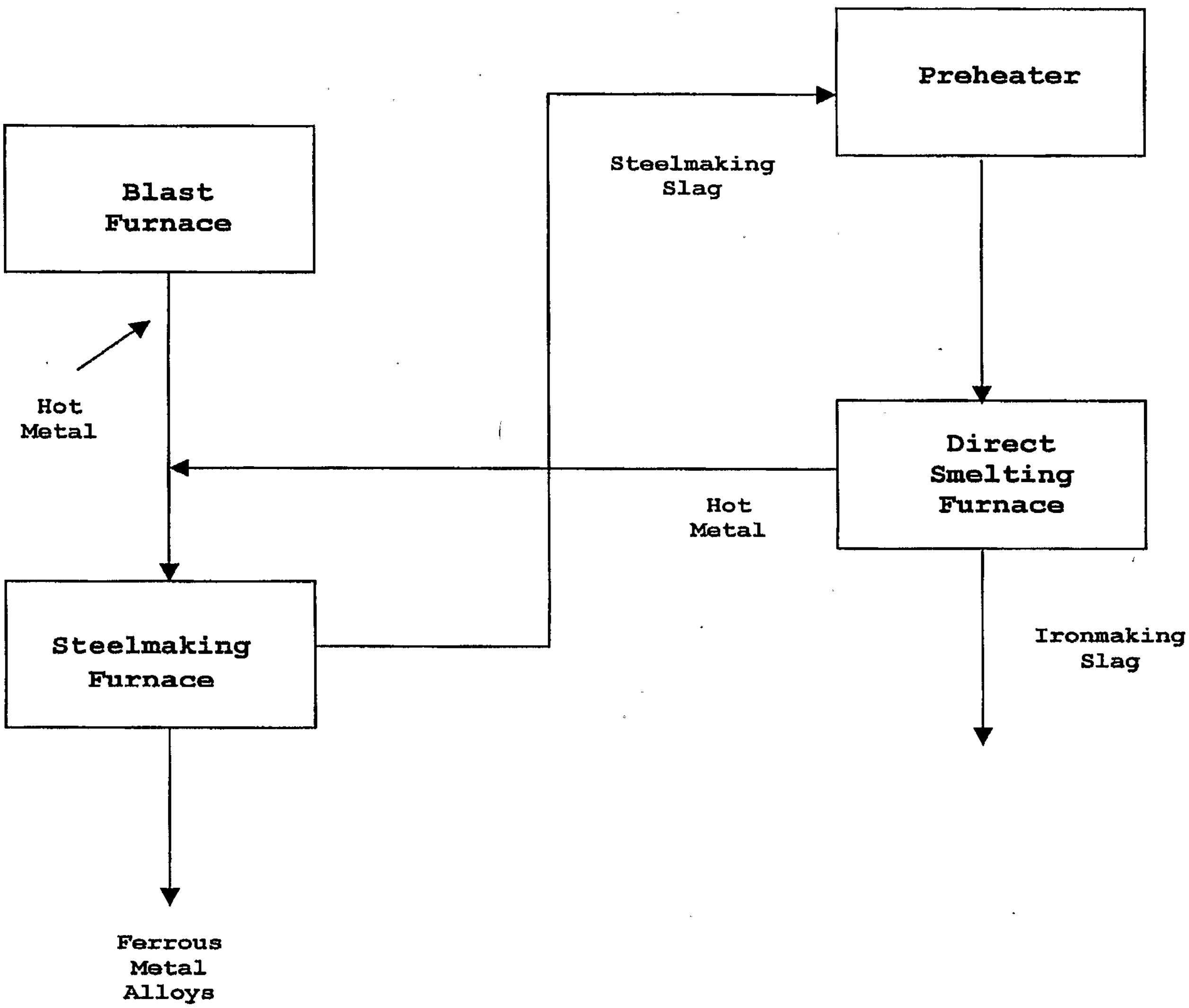

Iron Ore
Preheater
Coal
Steelmaking Slag Processing
Direct Smelting Furnace
Ironmaking Slag
Additional Flux(es)
Flux
Hot Metal
BOF
Steelmaking Slag
Ferrous Metal Alloy

Figure 3



Preheater
Blast Furnace
Steelmaking Slag
Hot Metal
Direct Smelting Furnace
Hot Metal
Steelmaking Furnace
Ironmaking Slag
Ferrous Metal Alloys